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Lordship's superior judgment, being with all possible respect,

My Lord,

Your Lordship's most obedient

humble servant,

London, Mar. 8,
1756.

Robert Dingley.

LXXV. *Thoughts on the Reverend Dr. Hales's new Method of Distillation by the united Force of Air and Fire. By William Brownrigg, M. D. F. R. S.*

To the Rev. Dr. Hales, D. D. F. R. S.

Dear Sir,

Whitehaven, Dec. 3, 1755.

Read Feb. 26, 1756. **I** Duely received the favour of your letter, written so long ago as the latter end of May last; containing an account of your important discovery of raising large quantities of water by the united operation of air and fire, in your new method of distillation. In obedience to your commands, on the receipt of your letter, I immediately set about considering to what uses your ingenious invention might be applied, besides the great one of supplying navigators with fresh water; and shortly after wrote out the inclosed paper relating to the improvement

provement of the fire-engine. This I presented, with your letter, to my worthy friend and relation, Mr. Carlisle Spedding, then superintendent of our coal-mines, who was an excellent mechanic, and had then the charge of five fire-engines, several of which had been under his care and management from the time, that those machines were first brought into use, and had himself made considerable improvements in them. He was pleased to express his approbation of what I had written, and was of opinion, that future improvements of the fire-engine must depend chiefly on the right solution of those two propositions, viz. " To increase the quantity of steam from a given vessel and a given heat, by means of mechanical agitation; and, to augment the elastic force of a given quantity of steam by means of fire:" and wished, that proper experiments could be made in these matters, which he thought would prove too expensive for most private people. His untimely and much lamented death put an end to these enquiries; and a variety of necessary avocations prevented me from sooner communicating to you the result of them. They are chiefly conjectures, which experience must ripen into use. I dare not assert, that the theory is altogether faultless; therefore very unfit to appear before the public. The honour you did me of communicating my rough plan of a history of damps to the Royal Society, I esteem a particular mark of your kindness and affection; altho' that plan was only intended for your own private use, and would not have appeared before that respectable body, (especially in its present form) had it not

been for your partial regard to it. I should be sorry to see any part of it published in the *Transactions*, especially as I long ago laid aside the design, which from the answer I received to the letter, of which I sent you a copy, I did not then think myself at liberty to prosecute, and do not think, that I shall again find leisure to resume it. I have long been of opinion, that, in order to attain a perfect knowledge of the nature of the air, we must trace it from its hidden sources in the bowels of the earth; and must own myself ambitious of treading in your steps, and of prosecuting your enquiries concerning the nature of its vivifying spirit;

*Non ita certandi cupidus, quam propter amorem,
Quod te imitari avelo.*

With this view, I had collected, under proper heads, all that I found in authors relating to that subject; and had prepared an apparatus, and also made some experiments to discover what alterations were produced in various kinds of air by stagnation; and what effects the different kinds of air, as well simple as compounded, had on animals included in them; and by these and such-like experiments, I might perhaps entertain too sanguine hopes of making some useful discoveries concerning the nature, and even the component ingredients, of the vivifying aerial spirit.

An ingenious friend, on reading the account of your method of distillation, was pleased to suggest, that the quantity of steam might perhaps be increased by heating the air, that is forced through the water contained in the still. This might be done conveniently enough, by passing an iron pipe, that goes
from

rom the ventilator through the furnace, which oils the water in the body of the still.

Dear Sir,

Your most affectionate and

most obedient fervant,

W. Brownrigg.

Thoughts on the Rev Dr. Hales's new Method of Distillation by the united Force of Air and Fire.

Read Feb. 26, 1756. **I**N the process of distilling sea water, as described by the reverend Dr. Hales, the great increase of vapour raised by his method, above what is raised by the common method of distillation, may be attributed, chiefly, to the violent agitation of the water contained in the body of the still, by the motion of the air continually pressed through it. Although the air, by attracting the watry particles, may also contribute to produce this effect. It is however certain, that a simple mechanical agitation of warm water will greatly promote its evaporation, by increasing its surface, from whence the vapours arise, and by putting its heated particles in a brisker motion, and exciting between them actions and reactions, and so disposing them to fly off in elastic vapours.

Of this we have instances in warm water, when stirred about in vessels, or poured out of one vessel into another; from which the vapours visibly arise
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in larger quantities than from the same water, when it is not moved by such mechanical agitation.

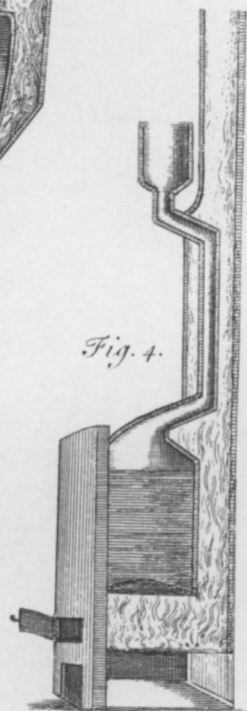
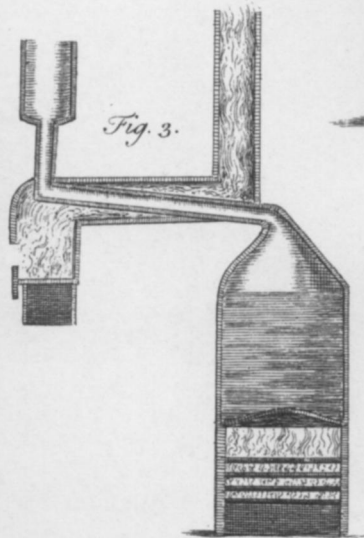
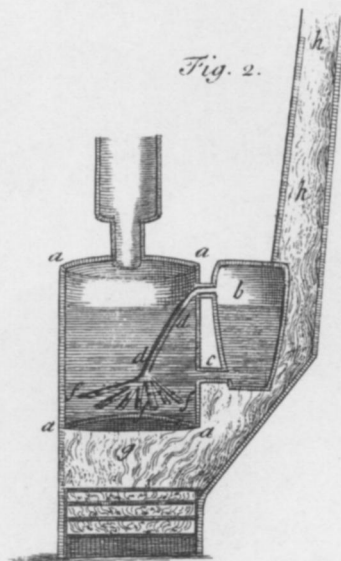
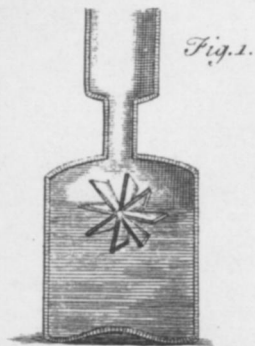
This excellent invention of Dr. Hales may probably be applied to other purposes besides that, which he had principally in view, viz. the distilling of seawater with greater ease and expedition, with less fuel, and in smaller vessels, than has hitherto been practised, for the benefit of navigators.

It might be of singular use, if it could be applied in the fire-engine. The great expence of large boilers in the construction of that machine, and the vast consumption of fuel in the working of it, render its uses much less extensive than they would be, could those expences be contracted. Various contrivances have with this view been tried; and it is to be wished, that others could be discovered, that would more effectually answer the end proposed.

But air cannot be applied, in this engine, to increase the quantity of the elastic steam, since it would pass with the steam from the boiler into the cylinder, and prevent a vacuum from being there produced, and hinder the piston from moving therein.

A mechanical agitation of the water in the boiler of the fire-engine may however be produced by other means, so as that a larger quantity of steam may probably be raised than can be effected in engines as commonly now constructed; by which means the expences of constructing and working those useful machines may perhaps be greatly lessened.

If, for example, the boiling water, instead of being agitated by air, as in Dr. Hales's method, was briskly stirred about by a wheel placed in the boiler of the fire-engine; it is probable, that by this means
the



the quantity of elastic vapour raised might be considerably encreased, and less fuel and a less boiler might then serve the purpose. The wheel might be turned round by the water drawn up by the engine; or might receive its motion from the beam of the engine by means of a crank; or a labourer might be employed in turning it round with the hand. See TAB. XVI. Fig. 1.

But the desired effect might, in all probability, be better produced by means of elastic steam driven briskly through the boiling water. The steam of water, as an elastic fluid, possesses many of the properties of common air.

Like air, when driven briskly from the æolipile, it is observed to blow up fire; and when forcibly driven through water, will doubtless produce the the same agitation therein, as is done by common air in Dr. Hales's experiment; and may probably have the like effect with air, in elevating a larger quantity of elastic vapours.

In order to excite an agitation in the boiling water of a fire-engine, by means of elastic steam, the following simple and easy method may be tried.

Fig. II.

aaaa. The boiler of the fire-engine.

b. An æolipile, or smaller boiler, annexed to the larger, receiving boiling water from it by the pipe (*c*), and continually emptying strongly elastic steam into it, by the alembic and tube (*dd*); which tube towards the bottom of the boiler is divided into many smaller tubes (*fff*)

perforated with holes, thro' which the steam passing produces a violent agitation in the water contained in the large boiler, and so increases the quantity of elastic steam.

The flame of the fire (*g*) ascending up the chimney (*bb*) may in its passage heat the water in the æolipole (*b*).

N.B. Either, or both, of the above contrivances may be applied to the boiler of an alembic, in the distillation of sea water for the use of navigators, in imitation of the method invented by the rev. Dr. Hales.

Further Experiments relating to the Fire engine, by lessening the expences of constructing and working it.

Theory.

It is found by experiments, that, *cæt. paribus*, the elasticity, or expansive force of common air, is in proportion to its density. And also that *cæt. par.* its elasticity is proportional to its degree of heat. And therefore, that its elasticity is proportional to its degree of heat,

The same probably holds true in other elastic fluids; and particularly in the steam of water; since, like all other bodies, it is capable of rarefaction (at least to a certain degree) by heat; and its elasticity, or expansive force must augment in proportion to the degree of heat which it receives.

Ex-

Explanatory Example.

Let us suppose, for example, that the heat of the steam in the boiler of a fire-engine is now 300 degrees of Fahrenheit's thermometer; it is evident, that if the same steam could, by any art, be heated to 600 degrees, its expansive force would be greatly increased; so that a much smaller quantity of steam thus heated would overcome the pressure of the air, and elevate the piston of the fire-engine, than is now applied for that purpose. And this smaller quantity of steam might be raised in smaller vessels, and with less fuel than is now used in the working that engine.

Practical Observations.

The heat of the steam now applied must be nearly the same with the heat of the water, from which it is raised. The heat of boiling water, in open vessels, is found, at a medium, about 212 degrees in Fahrenheit's thermometer; in close vessels, it is often considerably greater; but, in the boiler of the fire engine, can scarce exceed 300 degrees; it is certain, that it never approaches near to the heat of melted lead, since the sides of the boilers are often made of that metal. And it is observed, that the fire, when it touches the sides of the leaden boiler, where it is only filled with steam, does not melt the lead; the steam having the same effect with water in keeping the lead cool, to which the fire is applied.

From the following instance it nevertheless seems probable, that the steam of water may be brought to so great a heat, as to melt lead, to which it is applied. The pipe, which supplied the boiler of a fire-

engine with water, was by some accident stopped; and the water in the boiler was so exhausted, that the crown of the boiler, (or the middle part of the iron bottom, which is most elevated) became quite dry, and was heated red hot. And altho' there was only so small a quantity of water remaining in the boiler, the engine ceased not to work; but, on the contrary, was observed to move with unusual briskness; until at length, the strongly heated, and extremely rarified steam melted the pewter, where-with the joints of the top of the boiler (which was of copper) were soldered, and burst through them with great impetuosity.

Conclusion from the foregoing Experiments and Observations.

The foregoing experiments seem to prove, that the steam of water is capable of being heated and rarified to a much greater degree than the steam is heated, which is now applied in the fire-engine; and that the expansive force of steam is greatly increased by heat, and consequently, that a much smaller quantity of steam, most strongly heated and rarified, will work an engine, than is now applied of cooler steam: Which smaller quantity of steam may be raised in smaller vessels, and with smaller fires, than are now used in working those engines.

Practice.

The steam of water may probably be heated and rarified to a very great degree, for the use of the fire-engine, by the following method.

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To the head of the boiler let a pipe of cast iron be fitted nearly in an horizontal position, as in Fig. 3. but inclining a little towards the boiler; and let this pipe be continually kept red hot, by the fire of an air-furnace, through which it may pass; and thro' this pipe let the watry steam be conducted to the cylinder of the fire-engine.

Or the steam may be rarified by making it pass from the boiler to the cylinder, through an iron pipe or cylinder fixed in the flue of the furnace, of which contrivance a rude sketch is given in Fig. 4.

N. B. The evaporation from the boiler may perhaps be considerably quickened by the rarefaction of the steam.

It may not be improper to make trial of one or both of the above methods of heating the steam, or of other methods, that are more commodious; and also to add to the boiler the above recommended apparatus for raising a larger quantity of steam, by means of mechanical agitation. The fire-engine, as first invented by Savery, was rude and imperfect; and since his time many ingenious men have been continually making improvements therein; neither doth it yet seem to have attained to its greatest degree of perfection. There is even reason to hope that, by one or both of the methods here pointed out, viz. (either by encreasing the quantity of steam, or by augmenting its force) it may be brought to work with much smaller boilers, and with a very moderate expence of fuel; and under such circumstances it might be applied to a vast variety of purposes, and would become of much greater use to mankind.